Understanding signal generation and how systems work amounts to understanding signals, the nature of the information they represent, how information is transformed between analog and digital forms, and how information can be processed by systems operating on information-bearing signals. This understanding demands two different fields of knowledge. One is electrical science: How are signals represented and manipulated electrically? The second is signal science: What is the structure of signals, no matter what their source, what is their information content, and what capabilities does this structure force upon communication systems?

# 1.4 The Fundamental Signal

## 1.4.1 The Sinusoid

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The most ubiquitous and important signal in electrical engineering is the **sinusoid**.

**Sine Definition**

$$s(t) = Acos(2\pi ft + \phi) or Acos(\omega t + \phi)$$

***A*** is known as the sinusoid's **amplitude**, and determines the sinusoid's size. The amplitude conveys the sinusoid's physical units (volts, lumens, etc). The **frequency*f*** has units of Hz (Hertz) or $s^{-1}$, and determines how rapidly the sinusoid oscillates per unit time. The temporal variable ***t*** always has units of seconds, and thus the frequency determines how many oscillations/second the sinusoid has. AM radio stations have carrier frequencies of about 1 MHz (one mega-hertz or 106 Hz), while FM stations have carrier frequencies of about 100 MHz. Frequency can also be expressed by the symbol ω, which has units of radians/second. Clearly,

$$\omega = 2\pi f$$

. In communications, we most often express frequency in Hertz. Finally, φ is the **phase**, and determines the sine wave's behavior at the origin (t =0). It has units of radians, but we can express it in degrees, realizing that in computations we must convert from degrees to radians. Note that if

$$\phi = -\frac{\pi}{2}$$

, the sinusoid corresponds to a sine function, having a zero value at the origin.

$$Asin(2\pi ft + \phi) = Acos(2\pi ft + \phi = -\frac{\pi}{2})$$

Thus, the only difference between a sine and cosine signal is the phase; we term either a sinusoid.

We can also define a discrete-time variant of the sinusoid:

$$Acos(2\pi fn + \phi)$$

. Here, the independent variable is n and represents the integers. Frequency now has no dimensions, and takes on values between 0 and 1.